Financ Mark Portf Manag (2016) 30:299–336
DOI 10.1007/s11408-016-0272-x

The impact of mobile payment on payment choice

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Published online: 19 July 2016

Abstract This paper investigates the effect of mobile payment on the adoption and use of traditional payment instruments such as cash, checks, and credit, debit and prepaid cards at the point of sale (POS). Data are from a 2012 representative survey on consumer payment choice in the United States. Using discrete-choice random utility models to simulate consumer behavior, the estimation provides two major findings. First, mobile payment does not replace physical payment cards, but is likely to substitute for paper-based payment methods such as cash and checks at the adoption stage. Second, mobile payment does not statistically significantly influence the choice of payment means at the POS in terms of usage. However, there is suggestive evidence that it is complementary to card payments and a substitute for paper-based payment instruments. The findings highlight the potential social welfare gains of mobile payment and provide key insights into challenging issues for the private industry sector. This paper furthermore offers novel evidence on the impact of mobile payment on the use and adoption of existing payment instruments and contributes to the literature on consumer payment choice.

Keywords Mobile payment · Payment behavior · Payment innovation · Retail payments · Payment cards

JEL Classification D12 · G21 · O33

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1 Introduction

The availability of an increasing number of different payment instruments and of new online payment opportunities offers individuals various payment alternatives from which to choose. For instance, these days, consumers can select from among at least nine payment instruments in the United States that—apart from cash—either authorize the transfer of money or can access funds in checking and other deposit accounts to initiate payments (Schuh and Stavins 2014). Traditional banking payment services are facing increasingly fierce competition from novel and established nonfinancial companies such as Paypal, Google, Apple and Square, to mention just a few. These companies are attempting to gain market share in the retail payment markets with innovative products such as mobile payment that offers technological advances in payment processing and more convenience.[1] Therefore, the effects on consumer payment choice of mobile payment systems have been attracting increasing attention from researchers.

This paper studies the effect of mobile payment on the adoption and usage patterns of traditional payment instruments used at the point of sale (POS) and provides empirical evidence of actual changes in the composition of payment instrument portfolios as well as the instruments' deployment. Mobile payment can be used to make purchases and, therefore, may compete or complement current POS payment means (e.g., cash, checks, and credit, debit and prepaid cards). Mobile payment also offers a new access channel to account-based payment services such as online banking payments and bank account number payments (Kim et al. 2010). For the purpose of this study, however, POS payments are exclusively focused on since they account for the majority of consumer payments in the United States (Schuh and Stavins 2014).[2] The multiple fields of application and the high market penetration of mobile phones suggest that mobile payment may become a very popular means of payment. The paper, therefore, aims to provide insight into the complementing or substituting patterns of mobile payment and its potential welfare gains.

This paper is motivated by recent developments in payment markets, in which innovative mobile payment products have been frequently launched and the interrelation between payment alternatives is still unclear. Understanding these effects is important for the following reasons. First, consumer payment instrument choices for transactional purposes significantly affect the efficiency and effectiveness of an overall payment system, which in turn determines financial stability. Since the payment system in the United States predominantly relies on paper-based payment methods (Schuh and Stavins 2014), which cause high inefficiencies and high operation costs—for instance, due to the handling and distribution of cash—a shift to more electronic payments would confer an overall economic surplus (cf. Schmiedel et al. 2013). In

[1] Mobile payment is here defined as any payment that is authorized, initiated, or confirmed through a mobile device (Au and Kauffman 2008). It is usually debit and credit cards that determine the underlying payment process and settlement of payment. However, other forms such as bank account deduction or charges to phone bills are also common. The reader is referred to Liu et al. (2015) for a survey of recent changes in the mobile payment technology ecosystem.

[2] According to Schuh and Stavins (2014), 68.1 % of the total average monthly payments a consumer made in 2012 were non-bill payments.

general, substituting electronic payment instruments for cash is found to be associated with decreasing social costs (e.g., van Hove 2008; Humphrey et al. 2001). In addition, a transfer of conventional card payments to mobile payments may create economic value due to expected lower fee structures. Investigating these effects is supported by the strategic plan for 2012–2016 issued by the Federal Reserve Financial Services in the United States, which highlights enhancing the understanding of end-user needs for and barriers to payment system efficiency and speed (Pianalto 2012).

Second, comprehending and anticipating the impact of mobile payment and its implications for traditional payment services is fundamental since mobile payment could create market disruptions and threaten financial stability. For instance, mobile payment—especially applications that are operated by non-bank market players—may raise new policy issues and challenge the existing regulatory framework posing new liability issues. Providing detailed information on the effects and implications of mobile payment to policymakers and regulatory authorities could facilitate their decision-making processes in regard to this new financial landscape.

Third, assessing the impact of mobile payment is also relevant to other market participants, especially those in the private industry sector. On the one hand, banks and other financial intermediaries may experience eroding revenue streams due to these new mobile payment applications. On the other hand, mobile network operators (MNO) may benefit from new revenue streams stemming from charging conventional payment service providers for the right to undertake payments using their systems. The findings of this paper will, therefore, provide information to mobile payment stakeholders of the private industry that will be useful in making strategic and investment decisions.

This paper contributes to the literature on payment economics with respect to consumer payment choice and sheds light on the dynamics between mobile and traditional payment methods. To the best of my knowledge, there has not been any literature solely targeting the effect of mobile payment on conventional payment means, a lacuna mentioned by Dahlberg et al. (2008) and more recently reemphasized by Dahlberg et al. (2015). However, a few disruption analysis studies conclude that card payments would continue to be preferred to mobile payments from an industry point of view and that the latter tend to be more of a complement than a substitute for traditional payment methods in Switzerland (cf. Ondrus and Pigneur 2005, 2006a, b). In contrast, others propose that mobile payment reduces the use of central bank cash as well as credit and debit card payments (e.g., Garcia-Swartz et al. 2002). Polasik et al. (2013) argue that contactless mobile payment, used for proximity payments at the POS, will lead to a breakthrough in payment markets due to its superior time efficiency compared to cash. It is thus ambiguous what effect mobile payment will have. Consequently, this paper provides better knowledge of and empirical evidence on consumer payment habits and how they have changed in the context of mobile payment.

This paper is unique in several regards. First and foremost, it is the first study to gauge the impact of mobile payment on the array of traditional payment methods used at the POS. Second, the richness and quality of a unique data set allow for a detailed assessment of the impact of mobile payment technologies on conventional payment instruments, as well as in terms of adoption rates and usage behavior. Third, the individual-consumer-level data set enables estimating random utility models that quantify the effect of mobile payment for varying control variables. From this vantage point, substitution patterns across the current payment instruments will be evaluated and potential market disruptions will be clarified.

To this end, discrete-choice econometric models are applied on the probability of adopting and using conventional payment instruments such as cash, checks, and debit, credit, and prepaid cards with regard to mobile payment at the POS. Drawing data from the 2012 survey of consumer payment choice (SCPC) in the United States, this analysis yields the following important findings. First, mobile payment statistically significantly increases the probability of possessing all available payment instruments at the POS by roughly 2 % points and reduces the likelihood of adopting payment portfolios comprising checks and only cash (the extensive margin). This implies that mobile payment is not a substitute for physical payment cards, but does act as one for paper-based payment products. Second, mobile payment does not statistically significantly impact consumer payment choice at the POS in terms of usage (the intensive margin) with the exception of prepaid card payments, which are positively affected by mobile payment. However, there is an indication that mobile payment can be regarded as complementary to traditional card payments and as a substitute for paper-based payment instruments such as cash and checks. The results may reflect the fact that the usage of payment instruments strongly depends on other factors, such as perceived characteristics of payment methods, individual habits, and automatism, among others.

The remainder of this paper is organized as follows. Section 2 discusses related payment literature that focuses on the choice of payment methods, including the literature on mobile payment. In Sect. 3, the framework of the random utility model is introduced and the theoretical background of its properties is provided. In Sect. 4, explanation of the identification strategy and the specification of the models used for estimation is given. The data are described in Sect. 5. Section 6 discusses the estimation results and compares the model specifications based on their overall fit of the data. A plausibility check is run in Sect. 7 to validate the results. Section 8 concludes.

2 Related literature

This paper is related to a growing body of work on payment economics dealing with the determinants of consumer payment choice. The bulk of empirical studies rely on individual-level survey data due to the general unavailability of accurate transactional-level data.[3] In sum, the payment literature concludes that the adoption and usage of electronic payment instruments is primarily determined by personal, transactional, and situational characteristics, as well as by payment instrument attributes. Price characteristics and financial incentives are also strong predictors of adoption and deployment.

[3] There are a few studies based on transactional-level data provided by stores (scanner data), banks or credit card companies (e.g., Cohen and Rysman 2013; Agarwal et al. 2010; Klee 2008; Rysman 2007). Other papers focus on consumer payment choice over time using aggregate data sources provided by central banks or payment systems (e.g., Humphrey et al. 1996, 2001; Snellman et al. 2001; Amromin and Chakravorti 2009).

Several studies find that socioeconomic and financial attributes of consumers are relevant to payment choice (Schuh and Stavins 2010; Borzekowski et al. 2008; Stavins 2001). Younger, more educated cohorts with higher incomes are more likely to use electronic payment instruments than are elderly, less educated people with lower incomes, who tend to prefer paper-based payment methods such as cash. One reason for this phenomenon is that the first group faces higher opportunity costs when using paper-based methods, which generally take more time to settle (Polasik et al. 2013). Other research discovers an influence of region and foreign background. For instance, consumer patterns of payment instrument usage are highly affected by the fraction of other people in the region using the same type of payment method (Stavins 2001). Kosse and Jansen (2013), using Dutch data, find that a foreign background continues to influence payment instrument choice even after migration; that is, migrants from cash-oriented countries are more prone to use cash even after they migrate.

A plethora of literature deals with the effect on payment choice of transaction size, type of good purchased, and spending location. The size of a transaction is a leading indicator for the choice of payment method at the POS (von Kalckreuth et al. 2014; Cohen and Rysman 2013; Klee 2008; Bounie and François 2006).[4] The bigger the transaction, the more likely it is that people will pay with payment cards. Conversely, cash usage dominates small-value purchases. In contrast to these findings, Bouhdaoui and Bounie (2012) and Eschelbach and Schmidt (2013) argue that payment choice is more driven by the outstanding amount of cash in the consumer's wallet than by transaction size.

There are a number of influential empirical papers that investigate the impact of price and financial incentives on payment choice. Overall, consumers are very price sensitive. For instance, many scholars find a very elastic response to fees and surcharges imposed on debit card transactions, inferring consumers to substitute for alternative payment methods (Koulayev et al. 2012; Stavins 2011; Borzekowski et al. 2008; Bolt et al. 2010).

There is separate literature that highlights the significant and positive effects of loyalty programs and other financial incentives (card discounts, points, cash-back, interest-free periods) on the use of payment cards instead of cash (Arango et al. 2015b; Carbó-Valverde and Liñares-Zegarra 2011; Ching and Hayashi 2010; Simon et al. 2010; Agarwal et al. 2010). Moreover, credit card charges inhibit credit card revolvers to pay with these cards and motivate revolvers to pay by debit card instead (Zinman 2009).[5]

With regard to mobile payment, this paper takes as its basis empirical work pointing out the importance of certain payment instrument attributes, including convenience, ease of use, speed, record keeping, and security, when choosing a payment method (e.g., Arango et al. 2015a; Ching and Hayashi 2010; Schuh and Stavins 2010; Klee 2008). Overall, these attributes are found to be more important than demographic variables. Mobile payment is viewed as being more convenient, cheaper, and capable of providing better records (Mallat 2007). It can, therefore, improve the attractive-

4 See Arango et al. (2013) for an international comparison.

5 See also Massoud et al. (2011) who find that card interest rates are direct substitutes for card penalty fees, which are increasing in customer risk.

ness of electronic card payments, as it enhances their convenience by technological modifications (Jonker 2007). Conversely, personal experience with mobile payment is found to negatively influence cost-conscious payment choice behavior such as choosing cash at the POS (European Commission 2013).[6] This analysis aims to fill the gap in understanding these mechanisms.

In another vein, mobile payment is also extensively studied from the perspective of behavioral decisions and intentions in regard to innovations (for a synopsis and relevant references, see Dahlberg et al. 2008, 2015).[7] The adoption and usage of mobile payment are found to be influenced by the relative importance of certain factors such as trust, usefulness, ease of use, external influences, and personal traits, among others (Xin et al. 2015; Liébana-Cabanillas et al. 2014; Yang et al. 2012; Kim et al. 2010). Perceived ease of use, perceived usefulness, and trust are found to be the most important factors in the context of mobile payment use (Dahlberg et al. 2015). On the contrary, Mallat (2007) shows that the relative advantages of mobile payment are different from those of traditional adoption theories, in that it offers ubiquity of payment, independence of time, queue avoidance, and the ability to complement cash payments.

3 Model specification of payment choice

The behavioral model of payment choice is derived from the random utility framework, which explains decision behavior (cf. Train 2009). The description of payment decisions in discrete-choice models is based on the utility maximizing choice between discrete alternatives and allows estimating consumer preferences between choices. Formally, there is a decision maker i who faces a choice among J payment alternatives where each alternative provides a certain level of utility. U_{ij}, $j = 1, \ldots, J$ is the utility level a decision maker faces when choosing payment method j. If $U_{ij} > U_{ik}$ for all $k \neq j$ holds, then the alternative j is selected. In other words, the payment alternative yielding the highest utility is the one that is chosen such that

$$V_{ij} = \max U_{ij}. \tag{1}$$

The decision maker's utility can be decomposed as

$$U_{ij} = V_{ij} + \varepsilon_{ij} \tag{2}$$

where V_{ij} is a function that relates observed factors to the decision maker's utility. This function is denoted $V_{ij} = V(X_i, S_j, \beta_j, \gamma)\forall j$, where the factors are attributes of decision maker X_i and of the payment alternatives S_j. It is called representative utility. V_{ij} also depends on unknown parameters β_j and γ, which have to be estimated. β_j relates the attributes of decision maker X_i to his utility for choice j. γ shows the

[6] Cost-consciousness in this context represents transparency of payment charges.

[7] The reader is referred to Au and Kauffman (2008) for a survey of stakeholder issues in the field of mobile payment.

relationship between the decision maker and the alternatives to his utility for alternative j. Since some factors cannot be observed, and therefore are not included in V_{ij}, but do affect utility, they are captured by ε_{ij}, which is assumed to be randomly distributed. It can be viewed as the error made in evaluating alternative j. Since ε_{ij} is simply the difference between U_{ij} and V_{ij}, this decomposition is completely general.

The logit model is obtained by assuming that each ε_{ij} is an independently and identically distributed extreme value (i.i.d.), implying homogeneous error variances. This distribution is referred to as extreme value type-I, sometimes called the Gumbel distribution, leading to the assumption of independence of irrelevant alternatives (IIA). Put differently, the consumer's preference for payment method j over method k is independent of the availability of other alternatives.[8] The density and cumulative distribution of ε_{ij} is, respectively,

$$f(\varepsilon_{ij}) = \exp(-\varepsilon_{ij})\exp(-\exp(-\varepsilon_{ij})) \tag{3}$$

and

$$F(\varepsilon_{ij}) = \exp(-\exp(-\varepsilon_{ij})). \tag{4}$$

Under this assumption, the probability that decision maker i chooses payment alternative j over k is given by

$$\begin{aligned} P_{ij} &= \text{Prob}(U_{ij} > U_{ik}, \forall k \neq j) && (5)\\ &= \text{Prob}(V_{ij} + \varepsilon_{ij} > V_{ik} + \varepsilon_{ik}, \forall k \neq j) && (6)\\ &= \frac{\exp(V_{ij})}{\sum_{k=1}^{J}\exp(V_{ik})}. && (7) \end{aligned}$$

Equation (7) requires that the probabilities lie between zero and one and that they must sum to one. That the above choice probabilities lead to i.i.d. extreme value distributed errors was proven by McFadden (1973). The basic setup in Eq. (7) is referred to as the multinomial logit model (MNL), where the utility of all payment alternatives depends on the same factors, such as personal characteristics X_i, resulting in the binary logit model for $J = 1$. In the conditional logit model (CL), the utility of each payment alternative solely depends on attributes S_j of that alternative, which vary across alternatives. The conjunction of these models is the mixed conditional logit model where both alternative- and case-specific variables are included. These models allow inferring consumers' structural behavioral responses using the estimates of the model to perform counterfactual experiments in the consumer choice set. Because the logit probabilities take a closed form and are fairly easily computed, the traditional maximum likelihood procedure can be employed. For more details on the estimation procedure with maximum likelihood, see Train (2009).

[8] This problem is not very likely to occur so starkly in the context of payment instrument adoption since the choice set for payment methods at the POS is more finite. According to Borzekowski and Kiser (2008), the IIA assumption can be relaxed (on an aggregate level) if interaction terms between individual- and alternative-specific attributes are included.

These models, however, can explain taste variation only to the extent that tastes vary with the observed characteristics of individual i. In the presence of unobserved heterogeneity and to relax the IIA assumption, however, random coefficient models are necessary to avoid biased estimates. The nested logit model (NL) is regarded as the most tractable of these more general multinomial logit models, where the vector of the payment instrument error terms ε_{ij} exhibits the generalized value distribution (GEV) with the following cumulative distribution function (see Train 2009)[9]:

$$F(\varepsilon_{ij}) = \exp\left(-\sum_{l=1}^{L}\left(\sum_{j\in B_l}\exp(-\varepsilon_{ij}/\lambda_l)\right)^{\lambda_l}\right). \tag{8}$$

In this model, the alternatives J are partitioned into groups L with each alternative j belonging to an upper nest B. It can be thought of as a decision tree where the consumer first decides which nest to choose and then, within the nest, the alternative is selected. The error terms are allowed to be correlated within nests, but are uncorrelated across nests following an univariate extreme value distribution. Consequently, the probability that individual i chooses payment instrument h is:

$$P_{ih} = \frac{\exp(V_{ih}/\lambda_l)\left(\sum_{j\in B_l}\exp(V_{ij}/\lambda_l)\right)^{\lambda_l-1}}{\sum_{d=1}^{L}\left(\sum_{j\in B_d}\exp(V_{ij}/\lambda_d)\right)^{\lambda_d}}. \tag{9}$$

The parameter λ_l measures the correlation between alternatives within the different nests, that is, the degree of independence in unobserved utility. The higher λ_l, the less correlation within nests. According to Train (2009), the model is consistent with utility maximization for all values of the explanatory variables if λ_l is between zero and one, but only for some range of variables if λ_l is greater than one.

4 Identification strategy

In this section, the econometric models of consumer payment choice are described, which are directly derived from the random utility model set out above. Consumer payment behavior can be thought of as a two-step decision process. First, individuals decide whether to adopt a specific payment instrument, leading to the possession of different payment portfolios (the extensive margin). Second, they choose how much to use each adopted instrument in different contexts (the intensive margin). In this study, the two different processes are modeled independently and sequentially. This approach is selected since individuals usually have to first apply for a payment card before they can use it. In addition, this paper aims to provide evidence on the causal effect of mobile payment on either the adoption or the usage stage of traditional payment

[9] In addition, the mixed logit model allows for random parameters by varying the elements of β over the decision makers (see Train 2009).

instruments, rather than both simultaneously. On the one hand, mobile payment might replace physical payment cards due to electronic storing of payment card information, which negatively affects the adoption stage. On the other hand, mobile payment might promote electronic transactions, which positively affects the usage stage.[10] It is thus appropriate to consider these issues separately.

In Sect. 4.1, first, potential endogeneity issues related to empirical strategy are dealt with, allowing to correctly estimate the impact of mobile payment on payment choice. Second, the model specification that identifies the impact of mobile payment in the adoption stage is discussed in Sect. 4.2. Third, Sect. 4.3 sets out the econometric specification associated with the impact of mobile payment in the use stage.

4.1 Identifying assumptions

Based on the random utility model above, a stylized utility function to estimate the effect of mobile payment on the choice of payment method j is specified as follows:

$$U_{ij} = V(\mathrm{MP}_i, X_i, S_j) + \varepsilon_{ij} \tag{10}$$

The observed utility $V(\cdot)$ of individual i can be described as a function of mobile payment MP_i, consumer characteristics X_i, and payment instrument attributes S_j. ε_{ij} captures the measurement error. It is important to note that the variable MP_i has to be strictly exogenous to estimate an unbiased effect in the adoption and usage stage. However, several endogeneity issues are likely to appear in this context. First, selection bias may be prevalent due to unobservable factors causing consumers to adopt mobile payment and simultaneously decrease the number of paper-based payment methods. For example, consumers who are keen on new technology may have fewer paper-based payment means to begin with and be more likely to adopt innovations such as mobile payment. Similarly, this holds for usage of mobile payment. For these people, the utility of mobile payment is greater than for others.

Second, the direction of causation of MP_i is not obvious and could be the reverse. For instance, consumers who tend to pay less often with cash may be more prone to use innovative payment alternatives such as mobile payment.[11]

To obtain an unbiased causal parameter of MP_i, the aforementioned endogeneity issues can be largely circumvented by including individuals' perceptions of the characteristics of traditional payment instruments, thus capturing consumer preferences that otherwise would have been unobserved heterogeneity (cf. Ching and Hayashi

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10 Koulayev et al. (2012) develop a structural model of simultaneous adoption and use of payment instruments accounting for the amount of usage at the time of adoption while at the same time identifying the effect of use on adoption.

11 Another important endogeneity issue stems from the two-sided structure of the payment market where network effects are dominating. In other words, the interdependence of supply and demand for payment methods by merchants and consumers, respectively, results in feedback effects. One result could be higher utility for consumers who have adopted payment alternatives that are ubiquitously accepted by merchants. Consumers' perceived acceptance of payment methods can largely explain their various payment choices, which is what the survey of consumer payment choice (SCPC) contends (see below). However, due to data restrictions, an adequate control for this issue from the seller's point of view is not possible.

2010; Schuh and Stavins 2010; Jonker 2007). Moreover, assessing attitudes toward mobile payment allows controlling for heterogeneous effects of mobile payment across consumers and for other unobservables such as personal affinity for innovation.[12] Therefore, consumer preferences for payment alternatives can be fully explained by the alternatives' perceived characteristics, thus removing unobserved heterogeneity.

Nevertheless, it is completely plausible that the error terms could be correlated across payment alternatives since different groups of payment methods have similar unobservable characteristics. Such a circumstance would violate the IIA assumption. For instance, paper-based payment methods such as cash are anonymous, but also transparent (that is, it is hard to ignore the "pain of paying"), whereas using a payment card can mask the pain of paying, but leaves a data trail and offers (nearly) unlimited liquidity and credit. Additionally, payment decision making is considered to be largely habitual and unconscious (van der Horst and Matthijsen 2013), implying that consumers often have preferences for a certain type of payment instrument, be it paper or plastic. While the IIA assumption is likely to be violated in the usage stage due to the above-mentioned arguments, it is assumed to hold true in the adoption stage. The rationale is that it is unlikely that choosing a specific payment instrument portfolio is dependent on whether there is an option to choose another bundle.

Another methodological issue pertains to sample selection in the usage stage, as the adoption of payment instruments is a prerequisite for their usage. However, since the penetration of available POS payment instruments is relatively advanced (see Table 2) and assuming that the adoption and use decisions are made sequentially and not simultaneously, sample selection bias in the usage stage should be negligible. In support of this, evidence is provided by Schuh and Stavins (2013), who found that the Mills ratios of the first-stage probit models in the usage stage of POS payment means are insignificant in the majority of cases. A similar issue arises in the context of mobile phone ownership, seeing as such devices are necessary for mobile payment. However, because the rate of mobile phone diffusion is relatively high (around 95 %), this should not be a problem.

4.2 Estimating the adoption of payment instruments

Specification of the utility function is crucial to identification of the effect of mobile payment in the adoption stage. To this end, work by Schuh and Stavins (2013) is referred. The econometric model using the (mixed) conditional logit method is estimated. Since consumers are very heterogeneous in their adoption patterns of payment instruments (Schuh and Stavins 2014), that is, they generally adopt several different payment methods instead of a single instrument, it makes sense to proceed by determining the observed individual payment portfolios, each of which is comprised of instruments solely applicable at the POS. Doing so has the advantage of identifying an exhaustive, mutually exclusive, and finite number of discrete alternatives, which is a prerequisite of the conditional logit model.

[12] It is conceivable that consumers who rate characteristics of mobile payment more positively than others have higher coefficients than consumers who rate these characteristics less favorably.

Available payment instruments $j = 1, \ldots, J$ at the POS are cash, check, credit card, debit card, and prepaid card, and any or every combination of them.[13] Following the approach in the spirit of Koulayev et al. (2012), the consumer selects bundle $b \in B$, where b is a subset of all possible sets B of payment instruments. Assuming that every consumer adopts cash, there are four payment choices remaining, leading to the maximum number of different payment portfolios $B = 16\ \ (2^4)$. Thus, individual i obtains the following utility from choosing bundle b:

$$U_{ib} = \alpha \mathrm{MP}_i + \beta X_i + \gamma Y_i + \delta Z_i + \lambda \overline{\mathrm{RC}}_b + \varepsilon_{ib}, \tag{11}$$

where individual i derives utility from choosing payment portfolio b. MP_i takes the value of one if consumer i has used any form of mobile payment. The set of demographic variables X_i includes age, gender, education and household size. The vector Y_i encompasses employment status and income. Z_i consists of a dummy indicating whether the respondent had ever been bankrupt in the 12 months prior to the survey. In addition, the perceived assessment of mobile phones, mobile phones with Internet access, voice calling, and texting in regard to security is included. $\overline{\mathrm{RC}}_b$ is a set of relative measures of perceived security, setup, acceptance, cost, records, and convenience of payment instrument j belonging to bundle b (see Sect. 5.2 for variable definition). It varies across payment portfolios (alternative-specific regressors). The case-specific regressors, which are constant over alternatives, comprise individual characteristics MP_i, X_i, Y_i, and Z_i. ε_{ib} represents the unobserved preference component that is related to the particular payment bundle and is assumed to be i.i.d.

4.3 Estimating the usage of payment instruments

Specification of the utility function in the usage stage hinges on Ching and Hayashi (2010) and Schuh and Stavins (2013). The model is estimated using the nested logit method that explains which payment instrument j is most frequently selected by consumer i for each transaction type h. For the analysis, two nests ($L = 2$) are constructed, where the paper-based payment methods cash and check share one nest (B_{paper}) and the remaining card-based payment alternatives (debit, credit, and prepaid cards) share another nest (B_{card}). The utility function to be estimated has the form

$$U_{ijh} = \alpha \mathrm{MP}_i + \beta X_i + \gamma Y_i + \delta Z_i + \lambda \overline{\mathrm{RC}}_j + \varepsilon_{ijh}, \tag{12}$$

where MP_i is a dummy variable for having used any form of mobile payment in the past 12 months, X_i is a vector of consumer demographics, Y_i is a set of financial variables related to individual i, Z_i are additional control variables, including the attitudinal data on consumer valuation of mobile payment, and $\overline{\mathrm{RC}}_j$ is a vector of relative attributes of payment method j perceived by individual i. The specific variables incorporated in the utility function are similar to those in the adoption stage (see Eq. 11).

[13] Note that money orders can also be used at the POS. However, since their adoption and usage is negligible, they are excluded from the analysis.

Accordingly, observed heterogeneity across individuals in the model is accounted for. To put it more simply, the marginal utility of payment method j in context h is different across consumers. Consumer i can choose among five payment instruments $j = 1, \ldots, J$ such as cash, check, credit card, debit card, or prepaid card to pay for three transaction types h such as total POS payments, which is further differentiated into retail payments and services payments.[14] Note that the adoption decision of available payment methods is refrained and hence every consumer irrespective of the number of adopted instruments is focused on.

5 Data

5.1 Source

Data from the Federal Reserve Bank of Boston that supports the Consumer Payments Research Center (CPRC), which regularly conducts the survey of consumer payment choice (SCPC), are used.[15] The cross-sectional data set conducted in October 2012 consists of 2065 participants whose responses were weighted to represent all U.S. consumers aged 18 years and older. The survey is implemented by the RAND Corporation as an online survey using RAND's American Life Panel (ALP). It is a unique, comprehensive, publicly available, and representative survey that provides detailed payment information from individual consumers with respect to nine common payment methods in the United States.[16]

The survey primarily measures the adoption and use of these payment instruments by employing a flexible reporting strategy to enhance recall and optimize accuracy in regard to the number of payments.[17] However, low-value payments, which are mostly cash, tend to be forgotten more easily due to their high frequency and low budget impact. Cleaning procedures were implemented for the number of monthly payments for each payment instrument by defining upper limits based on the number of adopted instruments and an extreme limit on the total number of monthly payments (300 total payments) (Schuh and Stavins 2014). In addition, the SCPC asks consumers to evaluate six payment instrument characteristics for each payment method. These ratings may be vulnerable to incomplete information, memory loss, estimation, or even subjective

[14] The SCPC partitions POS payments into a third type of payment such as person-to-person payments. However, only a minor share of transactions occur person-to-person, which is why the effect on this type of payment is not analyzed (see Sect. 5.2). Furthermore, the focus of the analysis lies on payments made through a retail establishment. Retail payments comprise purchases of goods at stores such as grocery stores, superstores, department stores, and drug stores. Services payments include purchases of services such as restaurants, bars, fast food, and beverages, transportation and tolls, doctor's visits, child care, haircuts, education, recreation and entertainment. Person-to-person payments are payments to people not made through a retail establishment such as payments for allowances, paying back a friend, or gifts (cf. Schuh and Stavins 2014).

[15] The reader is referred to Schuh and Stavins (2014) for a comprehensive description of the data, a synopsis of the results, and detailed information about the collection process.

[16] These include cash, check, money order, traveler's check, debit card, credit card, prepaid card, online banking bill payments (OBBP), and bank account number payments (BANP).

[17] Typical periods used to measure the number of payments were during a week, a month, or a year.

Table 1 Usage of mobile payment on an annual basis

Variable	Mean	SD	N
Total	0.18	0.38	2032
Text/SMS	0.03	0.17	2032
Contactless	0.01	0.1	2032
Scanned a barcode	0.02	0.14	2031
Mobile phone's web browser	0.12	0.32	2032
Mobile application	0.07	0.26	2031
Device attached to mobile phone	0.06	0.24	2031

Note: usage describes the fact that respondents make the corresponding type of payment at least once in a typical year. Survey weights used

perceptions because consumers base their ratings on their own objective knowledge. The data set also provides rich information about consumer demographics, financial status, and state of residence. The estimates are not adjusted for seasonal variation, inflation, or item non-response (missing values).

5.2 Description

The survey specifically asks the question whether the respondent has made any form of mobile payment in the 12 months prior to the survey using a mobile phone. The act of making a mobile payment is sorted into specific activities to enhance recall. Table 1 presents the share of consumers who used mobile payment on an annual basis distinguished by different mobile payment types. 18 % of the respondents used mobile payment within the past year. Respondents mostly made mobile payments via a web browser (12 %), an application (7 %), or a device attached to the mobile phone (6 %), followed by sending a text message (3 %), scanning a barcode (2 %), or using the contactless feature (1 %). All these methods enable the purchase of goods and services at a stationary POS. However, the survey does not ask about the exact number of mobile payment transactions made or how mobile payments are generally funded.

The data set also provides insight into the adoption rates of available payment instruments at the POS (see Table 2). Not surprisingly, every respondent in the sample has cash, as it offers ubiquitous payment. Checks are also widely adopted (85 %) as are debit cards (78 %) and credit cards (72 %). Prepaid cards are somewhat less preferred (52 %). In addition to summary statistics, Table 3 provides a simple mean comparison test (*t* test) between mobile payment users (innovators) and non-users (non-innovators). Interestingly, innovators possess significantly more debit and prepaid cards than do non-innovators (15 and 13 % points, respectively), providing ad hoc evidence as to the preference for electronic payment methods.

However, as individuals usually adopt different payment portfolios, 16 possible payment bundles are constructed, assuming every individual adopts cash (see Table 4). As shown in Table 4, the majority of consumers in the sample have all five payment instruments available (around 30 %).[18] Roughly 28 % of individuals adopt a portfolio

[18] Available payment instruments at the POS include cash, checks, and debit, credit, and prepaid cards.

Table 2 Adoption rates of POS payment instruments

Variable	Mean	SD	*N*
Cash	1	0.02	2032
Check	0.85	0.35	2031
Debit card	0.78	0.41	2031
Credit card	0.72	0.45	2030
Prepaid card	0.52	0.5	2029

Note: survey weights used

Table 3 Differences in adoption rates of POS payment instruments

Variable	Non-innovator			Innovator			*t* test
	Mean	SD	*N*	Mean	SD	*N*	Mean diff.
Cash	1	0.02	1699	1	0	328	−0.00
Check	0.85	0.36	1697	0.87	0.34	327	−0.02
Debit card	0.76	0.43	1698	0.91	0.29	327	−0.15***
Credit card	0.71	0.45	1700	0.75	0.43	328	−0.04
Prepaid card	0.5	0.5	1701	0.63	0.48	328	−0.13***

Note: survey weights used. *t* test of mean differences between innovators and non-innovators. These values can differ from true values due to rounding and weighting. Significance levels 1 % ***, 5 % **, and 10 % *

Table 4 Adoption rates of payment portfolios

Bundle	Mean	SD
(1) All five instruments	0.303	0.46
(2) Cash, debit, credit, prepaid	0.012	0.107
(3) Cash, check, credit, prepaid	0.047	0.211
(4) Cash, check, debit, prepaid	0.074	0.261
(5) Cash, check, debit, credit	0.275	0.447
(6) Cash, check, debit	0.075	0.264
(7) Cash, check, credit	0.070	0.255
(8) Cash, check, prepaid	0.007	0.083
(9) Cash, debit, credit	0.009	0.096
(10) Cash, debit, prepaid	0.024	0.153
(11) Cash, credit, prepaid	0.005	0.073
(12) Cash, check	0.004	0.065
(13) Cash, debit	0.015	0.121
(14) Cash, credit	0.003	0.055
(15) Cash, prepaid	0.053	0.225
(16) Only cash	0.024	0.152

Note: survey weights used. $N = 2065$. Available payment instruments at the POS are cash, check, debit card, credit card, and prepaid card

of four instruments including no prepaid cards and around 7 % including no credit cards. The payment instrument portfolios “cash, check, debit” and “cash, check, credit” are held by around 7 % of individuals. A cash accompanied by prepaid cards portfolio is found for 5 % of consumers; around 2 % rely solely on cash.

Table 5 Differences in adoption rates of payment portfolios

Bundle	Non-innovator		Innovator		*t* test
	Mean	SD	Mean	SD	Mean diff.
(1) All five instruments	0.271	0.445	0.446	0.498	−0.175***
(2) Cash, debit, credit, prepaid	0.012	0.111	0.008	0.09	0.004
(3) Cash, check, credit, prepaid	0.055	0.228	0.011	0.104	0.044***
(4) Cash, check, debit, prepaid	0.075	0.264	0.066	0.249	0.009
(5) Cash, check, debit, credit	0.277	0.448	0.265	0.442	0.012
(6) Cash, check, debit	0.079	0.27	0.06	0.238	0.019
(7) Cash, check, credit	0.084	0.277	0.006	0.079	0.078***
(8) Cash, check, prepaid	0.006	0.075	0.012	0.111	−0.007
(9) Cash, debit, credit	0.008	0.089	0.015	0.122	−0.007
(10) Cash, debit, prepaid	0.021	0.144	0.037	0.188	−0.016
(11) Cash, credit, prepaid	0.006	0.079	0.001	0.031	0.005
(12) Cash, check	0.005	0.071	0	0	0.005**
(13) Cash, debit	0.015	0.123	0.013	0.115	0.002
(14) Cash, credit	0.004	0.06	0	0	0.004
(15) Cash, prepaid	0.055	0.227	0.049	0.215	0.006
(16) Only cash	0.027	0.161	0.01	0.1	0.017
N	1688		327		

Note: *t* test of mean differences between innovators and non-innovators. These values can differ from true values due to rounding and weighting. Significance levels 1 % ***, 5 % **, and 10 % *. Survey weights used

Additionally, a simple mean comparison test between innovators and non-innovators indicates significant differences in the adoption rates of payment bundles (see Table 5). First, mobile payment users have statistically significantly higher adoption rates of the payment portfolio encompassing all payment methods than do non-users (around 18 % points). Second, these consumers adopt the portfolios “cash, check, credit, prepaid”, “cash, check, credit”, and “cash, check” significantly less often than non-users. What these bundles have in common is the absence of debit cards, which seem to be linked to mobile payment users.

To estimate the impact of mobile payment on the use of traditional payment methods, Table 6 sets out descriptive statistics regarding the number of transactions made by different payment methods for various transactions types within a month. On average, consumers undertake roughly 43 POS payments a month, of which 24 are retail and 15 services payments.[19] These are usually paid in cash (around 16 POS transactions, nine and six retail and services transactions, respectively). Debit cards are the second often most used in these contexts: around 13 POS payments a month including eight and five retail and services transactions, respectively. Credit cards are somewhat less frequently deployed, with an average of nine POS transactions entailing six retail and

[19] Note that person-to-person payments account for around three transactions out of the total POS payments.

Table 6 Number of transactions per month by payment instrument and type

Variable	Mean	SD	Min.	Max.
Total POS payments	42.83	37.27	0	302.56
Cash	16.18	19.86	0	126.1
Check	2.84	5.7	0	41.67
Debit card	13.14	19.8	0	111.89
Credit card	9.42	18.1	0	130.45
Prepaid card	0.62	2.74	0	35
Retail payments	24.12	23.69	0	154.79
Cash	8.66	12.26	0	65.22
Check	1.23	3.3	0	30
Debit card	8.16	13.24	0	86.96
Credit card	5.63	11.47	0	78.27
Prepaid card	0.35	1.77	0	21.74
Services payments	15.37	16.48	0	130.45
Cash	5.61	8.93	0	86.96
Check	1.11	2.59	0	21.74
Debit card	4.66	8.4	0	80
Credit card	3.66	8	0	65.22
Prepaid card	0.27	1.53	0	26.09

Note: survey weights used. $N = 2041$. Subcategories do not exactly sum to main category due to rounding, weighting, and omitting money orders and person-to-person payments

four services payments. Checks, and most prominently, prepaid cards are not very popular for use at the POS (roughly three transactions).

Comparing the means of innovators and non-innovators with a t test reveals that the former undertake significantly more POS payments than the latter (approximately six additional transactions, see Table 7). This is also the case for debit card POS payments (around five transactions) while, in contrast, innovators make roughly one less check POS transaction than do non-innovators. Moreover, significant differences are observed in retail payments paid with checks and prepaid cards for mobile payment users (approximately 0.5 and 0.2 fewer transactions, respectively) as well as with debit cards (around three payments more). Innovators overall pay more frequently for services than non-innovators, namely around two transactions. They use their debit cards significantly more and checks less often for this transaction type, respectively (roughly 2 vs. 0.5 transactions). Note that the survey does not report which and how many card payments are initiated, authorized or confirmed through a mobile phone.

To analyze the effect of mobile payment on the usage of payment instruments, an individual dummy variable indicating the most frequently used payment method for every transaction type at the POS is constructed. Table 8 presents the payment choice frequencies in the sample and reveals that debit cards are the most preferred payment instrument followed by cash (around 37 vs. 35 %). 21 % of consumers most frequently choose credit cards, whereas checks and prepaid cards are less frequently selected as primary payment choice (4 vs. 1 %). Interestingly, consumers do not significantly vary their primary payment instrument across different transaction types such as retail and services payments.

Table 7 Differences of transactions per month by payment instrument and type

Variable	Non-innovator			Innovator			*t* test
	Mean	SD	Max.	Mean	SD	Max.	Mean diff.
Total POS payments	42.1	36.46	302.56	47.84	40.29	236.67	−5.74**
Cash	16.42	19.84	117.4	15.72	20.1	126.1	0.7
Check	3.09	5.95	41.67	1.82	4.33	41	1.27***
Debit card	12.28	18.89	108.71	17.55	23.25	111.89	−5.27***
Credit card	9.08	17.45	130.45	11.34	20.96	109.04	−2.26
Prepaid card	0.61	2.69	35	0.65	3	26.09	−0.04
Retail payments	23.74	23.04	138.46	26.8	26.37	154.79	−3.05
Cash	8.85	12.3	65.22	8.14	12.19	65.22	0.71
Check	1.33	3.41	30	0.82	2.82	23	0.50**
Debit card	7.67	12.73	86.96	10.74	15.26	86.96	−3.08***
Credit card	5.44	11	78.27	6.73	13.52	65.22	−1.28
Prepaid card	0.38	1.89	21.74	0.22	1.08	13.04	0.16*
Services payments	15.04	16.18	130.45	17.48	17.73	87.05	−2.44*
Cash	5.7	8.99	86.96	5.43	8.77	52.18	0.27
Check	1.23	2.76	21.74	0.59	1.58	15	0.65***
Debit card	4.29	7.84	80	6.55	10.48	52.18	−2.26***
Credit card	3.52	7.71	65.22	4.46	9.27	43.48	−0.93
Prepaid card	0.23	1.21	26.09	0.43	2.51	21.74	−0.20
N	1704			328			

Note: subcategories do not exactly sum to main category due to rounding, weighting, and omitting money orders and person-to-person payments. $N = 2,041$. For brevity, the minimum is dropped but equals zero for every type of payment. *t* test of mean differences between innovators and non-innovators. These values can differ from true values due to rounding and weighting. Significance levels 1% ***, 5% **, and 10% *. Survey weights used

Table 8 Payment choice frequencies in the sample

Variable	Total POS payments	Retail payments	Services payments
Cash	0.352	0.355	0.353
Check	0.040	0.044	0.069
Debit card	0.368	0.376	0.353
Credit card	0.210	0.216	0.214
Prepaid card	0.012	0.015	0.014

Note: survey weights used. The share of payment instruments most frequently used is displayed. Total POS payments do not include person-to-person payments

The survey also provides rich information about consumer financial and demographic characteristics. Table 9 compares individual attributes of innovators with those of non-innovators by a simple mean *t* test. Statistically significant differences are observable. Mobile payment users are generally younger, more educated and richer than non-innovators. They are mostly male, work, are more likely to already have

Table 9 Sample summary statistics

Variable	Non-innovator					Innovator					*t* test
	Mean	SD	Min.	Max.	*N*	Mean	SD	Min.	Max.	*N*	Mean diff.
Age											
<25	0.05	0.22	0	1	1704	0.09	0.29	0	1	328	−0.03***
25–34	0.21	0.41	0	1	1704	0.4	0.49	0	1	328	−0.21***
35–44	0.13	0.34	0	1	1704	0.24	0.43	0	1	328	−0.09***
45–54	0.2	0.4	0	1	1704	0.15	0.36	0	1	328	0.04
55–64	0.18	0.39	0	1	1704	0.08	0.28	0	1	328	0.11***
>65	0.22	0.42	0	1	1704	0.03	0.18	0	1	328	0.18***
Education											
<High school	0.08	0.27	0	1	1704	0.05	0.22	0	1	328	0.01
High school	0.37	0.48	0	1	1704	0.26	0.44	0	1	328	0.08***
Some college	0.28	0.45	0	1	1704	0.31	0.46	0	1	328	0.02
College	0.15	0.36	0	1	1704	0.24	0.43	0	1	328	−0.08***
Post graduate	0.12	0.33	0	1	1704	0.14	0.35	0	1	328	−0.02
Income (in 1000)											
<25	0.24	0.43	0	1	1701	0.16	0.37	0	1	328	0.05 **
25–49	0.26	0.44	0	1	1701	0.23	0.42	0	1	328	0.01
50–74	0.18	0.38	0	1	1701	0.21	0.41	0	1	328	0.00
75–99	0.12	0.32	0	1	1701	0.18	0.38	0	1	328	−0.02
100–124	0.1	0.29	0	1	1701	0.07	0.25	0	1	328	0.02
>125	0.11	0.31	0	1	1701	0.14	0.35	0	1	328	−0.06***
Employment											
Working	0.57	0.5	0	1	1704	0.78	0.42	0	1	328	−0.19***
Retired	0.23	0.42	0	1	1704	0.04	0.2	0	1	328	0.18 **
Unemployed	0.09	0.29	0	1	1704	0.1	0.3	0	1	328	−0.01
Others											
Male	0.47	0.5	0	1	1704	0.54	0.5	0	1	328	−0.07 **
Female	0.53	0.5	0	1	1704	0.46	0.5	0	1	328	0.07 **
Household size	2.9	1.59	1	11	1704	3.34	1.71	1	11	328	−0.39***
Bankruptcy	0.01	0.08	0	1	1693	0.03	0.18	0	1	326	−0.02***

Note: survey weights used. Bankruptcy refers to having been bankrupt in the past 12 months. *t* test of mean differences between innovators and non-innovators. These values can differ from true values due to rounding and weighting. Significance levels 1 % ***, 5 % **, and 10 % *

been bankrupt once, and live in larger households, all of which is in line with previous studies (see Sect. 2).

To sum up, the descriptives show that there are significant differences in the adoption and usage patterns of mobile payment users and non-users. There is suggestive evidence that mobile payment influences the adoption of particular payment portfolios—especially toward holding all payment instruments—and leads to increased usage of debit cards and decreased usage of checks for overall POS payments. In addition, consumers who are younger, richer, more educated and male are more likely to use mobile payment technology. As a whole, individuals in the sample most frequently pay by debit cards and cash at the POS.

As pointed out in Sect. 2, perceived characteristics of payment instruments explain a significant amount of the variation in payment methods. A major advantage of the SCPC is that respondents—both adopters and non-adopters of payment instruments—assessed attributes such as security, setup, acceptance, cost, records, and convenience for every payment instrument on an absolute scale from one to five, where higher numbers mean a more favorable assessment.

For the purpose of this paper, the perceived characteristics of every payment method applicable at the POS were constructed as the average of each respondent's perception of each payment method relative to every other payment method at the POS similar to the approach in Schuh and Stavins (2013). They were calculated as

$$\mathrm{RCHAR}_{ki}(j, j') \equiv \log\left(\frac{\mathrm{CHAR}_{kij}}{\mathrm{CHAR}_{kij'}}\right), \tag{13}$$

where k describes the six characteristics (security, setup, acceptance, cost, records, and convenience), i indexes the consumer, j relates to the payment instrument applicable at the POS, and j' is every other payment instrument besides j that is commonly used at the POS. For the baseline specification and to account for the number of available payment instruments, the log relative characteristics were transformed as

$$\overline{\mathrm{RC}}_{ki}(j) \equiv \frac{1}{J_i} \sum_{j' \neq j} \mathrm{RCHAR}_{ki}(j, j') \tag{14}$$

over all available POS payment instruments $J_i = 5$ for consumer i resulting in the average relative characteristics for each payment attribute k. For instance, $\overline{\mathrm{RC}}_{\mathbf{cost}\mathbf{i}}$(credit card) represents the average of the log ratios of the perceived credit card cost for consumer i to the cost of each of the other payment alternatives for consumer i. The construction is applied to every consumer regardless of the adoption stage of payment methods, that is, relative to all payment instruments.

However, to explicitly deal with the different bundles $b \in B$ in the adoption stage, the relative perceived characteristics $\overline{\mathrm{RC}}_{kib}$ of bundle b are constructed as

$$\overline{\mathrm{RC}}_{ki}(b) \equiv \frac{1}{\widetilde{J}_i} \sum_{j \in b} \overline{\mathrm{RC}}_{ki}(j), \tag{15}$$

where $\widetilde{J}_i$ is the number of payment instruments adopted by consumer i.

6 Results

In this section, the estimation results of the random utility model according to the adoption stage are discussed first (Sect. 6.1), thus evaluating the effect of mobile payment on the adoption patterns of payment portfolios. Then, the estimation results of the usage stage are presented (Sect. 6.2), examining the effect of mobile payment on the usage of payment instruments in different contexts.

6.1 Estimation results of the adoption stage

This section first presents the estimation results of the adoption stage regression. Second, the effect of mobile payment on the adoption of payment portfolios is discussed.

6.1.1 Results of the conditional logit model

The estimation results of the conditional logit model are reported in Tables 10 and 11. Testing for IIA with the Hausman–McFadden test implies that the model is well specified, that is, dropped alternatives are irrelevant in the majority of cases.[20] Additionally, a Wald test is employed that reveals that mobile payment creates a statistically significant improvement in model fit.[21] This test also demonstrates that the effects are not statistically different from each other in predicting the adoption of different portfolios compared to the base outcome.

Overall, corroborating evidence that mobile payment basically has a negatively, statistically significant effect on the probability of choosing all other payment portfolios relative to the probability of having adopted all five payment methods available, holding all else constant is found. For instance, it is less likely that individuals who have used mobile payment adopt payment portfolios including checks compared to the base outcome. Most prominently, they are significantly less likely to jointly adopt cash and checks, cash and credit cards, or to solely rely on cash.

Coefficients of the perceived attributes of payment instruments have intuitive signs and are highly statistically significant, indicating that a more positive rating increases the demand for one payment bundle while decreasing the demand for the remaining portfolios. In other words, utility of payment portfolios is increasing in perceived characteristics. For instance, consumers who rate the basket of adopted payment methods as relatively more secure and convenient are more likely to adopt it, which is in accord with previous studies (e.g., Schuh and Stavins 2015; Arango et al. 2015a). Education, age, being male, and having ever been bankrupt are statistically significant in most of the cases across bundles. The probability of adopting only cash, cash and debit cards, or cash and prepaid cards, for example, decreases as the level of education increases. Furthermore, the results illustrate that including attitudinal characteristics of mobile payment significantly explains heterogenous effects of consumers across payment portfolios.

However, coefficients are cumbersome to interpret in nonlinear models such as the conditional logit model, thus average marginal effects are provided in the next section.

20 Test statistics are not provided. The Hausman–McFadden test compares two estimators of the same parameter, one of which is consistent and efficient (IIA holds), while the other is consistent, but inefficient. The first estimator is obtained by a correctly specified model; the second is obtained by estimating the model on a restricted number of payment bundles (cf. Hausman and McFadden 1984).

21 Test statistics are not shown.

Table 10 Conditional logit estimates: adoption stage

Variables	DC/CC/SVC	CHK/CC/SVC	CHK/DC/SVC	CHK/DC/CC	CHK/DC	CHK/CC	CHK/SVC
MP	−0.327	−1.331***	−0.589**	−0.464***	−0.621**	−1.502***	−0.533
	(0.620)	(0.435)	(0.294)	(0.170)	(0.314)	(0.473)	(1.002)
Age	−0.180	0.044	−0.019	−0.064**	−0.148***	−0.047	−0.242**
	(0.142)	(0.049)	(0.047)	(0.027)	(0.045)	(0.048)	(0.108)
Age^2	0.001	−0.000	−0.000	0.001**	0.001**	0.001*	0.002**
	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
Education	−0.721***	0.123	−0.570***	−0.209***	−0.524***	−0.183*	−1.535***
	(0.170)	(0.096)	(0.097)	(0.061)	(0.119)	(0.105)	(0.521)
Working	−0.228	0.224	−0.519	−0.084	−0.134	0.198	1.537
	(1.073)	(0.320)	(0.321)	(0.194)	(0.329)	(0.304)	(1.039)
Retired	2.213*	0.359	−0.610	−0.006	−0.364	0.410	−17.312***
	(1.249)	(0.337)	(0.425)	(0.226)	(0.433)	(0.326)	(0.789)
Other employment	0.828	0.330	0.466	−0.021	0.110	−0.044	1.542
	(0.790)	(0.299)	(0.324)	(0.202)	(0.355)	(0.295)	(1.124)
Male	0.791	0.482**	0.380*	0.347***	0.436**	0.335*	−0.253
	(0.697)	(0.195)	(0.215)	(0.125)	(0.219)	(0.200)	(1.033)
Household size	0.082	−0.026	0.079	−0.068	−0.013	−0.137	0.177
	(0.130)	(0.069)	(0.073)	(0.045)	(0.086)	(0.107)	(0.257)
Bankruptcy	−16.515***	−16.571***	2.516***	−1.217	2.378***	−16.446***	−16.454***
	(1.058)	(0.546)	(0.736)	(1.091)	(0.766)	(0.514)	(1.520)
MP Internet security	−0.287	0.133	0.034	0.080	−0.087	0.079	−0.738**
	(0.478)	(0.127)	(0.134)	(0.079)	(0.140)	(0.133)	(0.366)

Table 10 continued

Variables		DC/CC/SVC	CHK/CC/SVC	CHK/DC/SVC	CHK/DC/CC	CHK/DC	CHK/CC	CHK/SVC
MP text security		0.367	−0.120	−0.107	0.191**	0.268*	0.282**	0.607
		(0.422)	(0.134)	(0.151)	(0.080)	(0.149)	(0.125)	(0.544)
MP voice security		0.014	−0.065	0.100	−0.139*	−0.107	−0.235*	0.448
		(0.452)	(0.124)	(0.131)	(0.075)	(0.129)	(0.121)	(0.476)
Security	1.205***							
	(0.266)							
Setup	2.891***							
	(0.434)							
Acceptance	1.382**							
	(0.566)							
Cost	1.019***							
	(0.330)							
Records	1.835***							
	(0.306)							
Convenience	2.762***							
	(0.406)							
Constant		3.547	−4.165***	1.463	1.444*	3.795***	−1.150	3.473
		(2.314)	(1.495)	(1.206)	(0.745)	(1.197)	(1.530)	(3.255)

Note: adopting cash (CSH), check (CHK), debit (DC), credit (CC), or prepaid card (SVC) as elements of the payment portfolio is the base outcome. Cash is an element of all payment portfolios. Base category for employment is unemployed. Bankruptcy refers to having been bankrupt in the past 12 months. MP is mobile payment. Robust standard errors in parentheses. The number of cases is 1987, the number of observations is 31,792, and the log(likelihood) is −3076. Income has been dropped due to collinearity. Significance levels are denoted as *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 11 Conditional logit estimates: adoption stage (Cont.)

Variables	DC/CC	DC/SVC	CC/SVC	CHK	DC	CC	SVC	CSH
MP	−1.209*	−0.208	−0.286	−16.980***	−0.887	−16.435***	0.209	−2.169**
	(0.703)	(0.424)	(1.282)	(0.501)	(0.600)	(0.797)	(0.478)	(1.063)
Age	−0.142	0.177	0.027	−0.274	−0.134	−0.289	−0.094	0.064
	(0.138)	(0.130)	(0.190)	(0.172)	(0.104)	(0.194)	(0.099)	(0.252)
Age^2	0.000	−0.003*	−0.000	0.003	0.001	0.003	0.000	−0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.003)
Education	−0.383	−0.630***	−1.304**	−0.192	−0.764***	−0.824	−1.306***	−1.021***
	(0.278)	(0.143)	(0.594)	(0.449)	(0.223)	(0.659)	(0.267)	(0.318)
Working	0.295	−0.406	1.893	0.956**	−0.486	−1.310	−1.425***	−1.005
	(0.930)	(0.459)	(1.505)	(0.421)	(0.524)	(0.812)	(0.516)	(0.737)
Retired	1.927	0.666	1.948	−1.476	−0.967	−17.143***	0.286	0.827
	(1.898)	(1.401)	(1.614)	(2.328)	(1.421)	(1.769)	(0.910)	(2.164)
Other employment	−0.700	0.511	1.412**	1.261	1.537***	−15.851***	0.906*	0.956
	(1.070)	(0.467)	(0.710)	(1.134)	(0.575)	(1.624)	(0.502)	(0.747)
Male	0.764	−0.207	0.696	2.131***	0.878*	1.338	0.152	1.840***
	(0.524)	(0.406)	(0.686)	(0.827)	(0.498)	(1.232)	(0.402)	(0.569)
Household size	−0.184	0.156	0.244	0.393	0.002	−0.133	0.009	0.084
	(0.234)	(0.103)	(0.223)	(0.244)	(0.153)	(0.415)	(0.107)	(0.171)
Bankruptcy	−16.608***	−16.216***	−16.185***	−15.324***	2.272*	−14.792***	−16.336***	−16.321***
	(0.906)	(0.740)	(1.015)	(1.509)	(1.232)	(1.068)	(1.119)	(0.991)

Table 11 continued

Variables		DC/CC	DC/SVC	CC/SVC	CHK	DC	CC	SVC	CSH
MP Iinternet security		−0.362	−0.070	0.241	−0.073	0.129	0.587	0.078	0.451
		(0.286)	(0.217)	(0.450)	(0.299)	(0.276)	(0.469)	(0.332)	(0.290)
MP text security		0.435	0.014	−0.092	0.431	0.396	0.441	0.459	−0.056
		(0.270)	(0.213)	(0.571)	(0.291)	(0.266)	(0.416)	(0.286)	(0.308)
MP voice security		−0.296	0.026	0.167	−0.928***	−0.271	−0.824***	−0.205	−0.023
		(0.351)	(0.168)	(0.424)	(0.268)	(0.321)	(0.289)	(0.285)	(0.281)
Security	1.205***								
	(0.266)								
Setup	2.891***								
	(0.434)								
Acceptance	1.382**								
	(0.566)								
Cost	1.019***								
	(0.330)								
Records	1.835***								
	(0.306)								
Convenience	2.762***								
	(0.406)								
Constant		2.754	−2.627	−5.455	0.314	1.468	4.182	4.800**	−1.719
		(3.133)	(2.502)	(3.405)	(4.028)	(2.990)	(5.493)	(2.022)	(4.890)

Note: adopting cash (CSH), check (CHK), debit (DC), credit (CC), or prepaid card (SVC) as elements of the payment portfolio is the base outcome. Cash is an element of all payment portfolios. Base category for employment is unemployed. Bankruptcy refers to having been bankrupt in the past 12 months. MP is mobile payment. Robust standard errors in parentheses. The number of cases is 1987, the number of observations is 31,792, and the log(likelihood) is −3076. Income has been dropped due to collinearity. Significance levels are denoted as *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

6.1.2 Average marginal effects

To quantitatively appraise changes in payment portfolio choice subsequent to mobile payment, the average predicted probabilities of choosing each of the payment bundles with and without having used mobile payment in the model is computed as

$$\mathrm{AME}_{\mathrm{MP}} = \frac{1}{N}\sum_{i=1}^{N}\left\{(\widehat{P}_{ij}|\mathrm{MP}_i = 1) - (\widehat{P}_{ij}|\mathrm{MP}_i = 0)\right\}, \tag{16}$$

resulting in the average marginal effect ($\mathrm{AME}_{\mathrm{MP}}$) of mobile payment for a typical person. The effect of mobile payment on the portfolio choice is evaluated as the difference in the predicted probabilities of having used mobile payment, while holding all other factors constant. In this way, substitution patterns across payment portfolios can be computed.

The predicted probabilities are set out in the first column in Table 12, which can be compared to the actual frequencies of payment portfolios in the sample (see Table 4). The overall fit of the model is fairly good seeing that the predicted choice probabilities correspond closely to the actual frequencies for the entire sample. In other words, the explanatory variables in the model predict the choice of payment portfolios rather precisely. This implies that every change in the observed variables, which leads to a change in the predicted probabilities, is actually closely related to the observed frequencies. However, the average predicted probabilities are somewhat more accurate for specific payment bundles, while they are less precise for other choices. This could be because some alternatives have considerably higher shares in the sample and are, therefore, better approximated than less preferred alternatives.

Average marginal effects (AME) of mobile payment for every choice alternative are set out in the third column in Table 12. The signs of the AME vary across payment bundles and the magnitude of the effects is very modest compared to the initial probabilities, meaning that the probability of adopting payment portfolios is not highly dependent on mobile payment.[22] There are two main findings: first, mobile payment increases the probability of adopting the payment bundle including all POS payment instruments by around 2.1 % points at the expense of reducing the probability of choosing portfolios primarily entailing checks (with fewer than five instruments) and cash as a sole instrument. The reductions range from −0.05 to −0.42 percentage points. Second, consumers are generally more likely to adopt payment bundles that encompass more than one payment card if they have mobile payment (maximum increase of +0.12 % points).

To conclude, mobile payment positively influences the probability of having all POS payment methods. This indicates that this type of payment does not replace physical payment cards. However, it does reduce the probability of adopting only cash and payment portfolios containing checks, of which include fewer than five instruments.

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[22] Attitudinal characteristics of payment methods are expected to have greater impact on the adoption choice (cf. Schuh and Stavins 2013).

Table 12 Adoption stage: average marginal effect of mobile payment

Bundle	Predicted prob.	Predicted prob. w/o MP	Average marginal effect
All	29.325	27.188	2.137
DC/CC/SVC	1.124	1.104	0.019
CHK/CC/SVC	5.076	5.458	−0.382
CHK/DC/SVC	8.340	8.618	−0.279
CHK/DC/CC	27.336	27.680	−0.342
CHK/DC	7.504	7.776	−0.273
CHK/CC	6.552	6.975	−0.423
CHK/SVC	0.715	0.726	−0.011
DC/CC	1.068	1.307	−0.240
DC/SVC	2.614	2.499	0.115
CC/SVC	0.472	0.463	0.008
CHK	0.452	0.504	−0.052
DC	1.835	1.980	−0.145
CC	0.264	0.352	−0.088
SVC	4.902	4.538	0.363
CSH	2.422	2.831	−0.409

Note: survey weights used. Numbers are in percentages and percentage points, respectively. CSH refers to cash, CHK to check, DC to debit, CC to credit, and SVC to prepaid card

This suggests that mobile payment is not a substitute for payment cards, but that it is for paper-based payment options.

6.2 Estimation results of the usage stage

In this section, the estimation results of the usage stage regression are discussed first. Second, the impact of mobile payment on the use of traditional payment instruments in different payment contexts is presented.

6.2.1 Results of the nested logit model

The estimation results of the usage stage regarding the transaction type of overall POS payments are displayed in Table 13. Tables 14 and 15 separately show the estimation results of the usage stage for retail and services payments, respectively. At the bottom of all models estimated, the dissimilarity parameters λ of both nests are presented, revealing highly significant results of the likelihood ratio test, meaning that the conditional logit model is strongly rejected in favor of the nested logit model, that is, there is strong evidence for correlated errors. The parameter λ of the nest comprising payment cards is always smaller than one, indicating that payment cards (credit, debit, and prepaid cards) are closer substitutes for themselves than for those payment instruments in the other group of paper-based methods. The same is not true for the nest comprising paper-based payment methods since λ is slightly greater than one.

Table 13 Nested logit estimates usage stage: POS payments

Variables		Check	Debit	Credit	Prepaid
MP		−1.465	0.108	0.034	0.493*
		(1.021)	(0.161)	(0.166)	(0.281)
Age		0.046	−0.019	−0.040	−0.040
		(0.079)	(0.025)	(0.025)	(0.055)
Age^2		−0.000	0.000	0.000	0.000
		(0.001)	(0.000)	(0.000)	(0.001)
Education		0.063	0.168***	0.243***	0.181
		(0.166)	(0.059)	(0.060)	(0.127)
Income		−0.103	0.076*	0.148***	−0.027
		(0.125)	(0.041)	(0.041)	(0.110)
Working		0.656	0.798***	0.736***	0.614*
		(0.510)	(0.180)	(0.184)	(0.330)
Retired		1.719**	0.632***	0.693***	1.291**
		(0.667)	(0.226)	(0.230)	(0.561)
Other employment		0.452	0.176	0.271	0.212
		(0.452)	(0.181)	(0.186)	(0.321)
Male		−0.668*	−0.586***	−0.520***	−1.062***
		(0.364)	(0.116)	(0.118)	(0.354)
Household size		−0.086	−0.060	−0.092**	0.050
		(0.137)	(0.041)	(0.043)	(0.063)
MP Internet security		0.106	0.180**	0.168**	0.317**
		(0.213)	(0.074)	(0.075)	(0.148)
MP text security		−0.414*	−0.048	−0.067	−0.205
		(0.240)	(0.077)	(0.079)	(0.140)
MP voice security		0.099	−0.001	0.019	−0.039
		(0.200)	(0.071)	(0.072)	(0.141)
Security	0.151***				
	(0.047)				
Setup	0.629***				
	(0.114)				
Acceptance	0.466***				
	(0.125)				
Cost	0.341***				
	(0.064)				
Records	0.430***				
	(0.075)				
Convenience	1.063***				
	(0.134)				

Table 13 continued

Variables		Check	Debit	Credit	Prepaid
Constant		−3.906	−0.740	−0.749	−0.688
		(2.597)	(0.683)	(0.698)	(1.268)
Observations	9230				
N	1846				
log(likelihood)	−1783				
Paper λ	1.287***				
	(0.306)				
Card λ	0.257***				
	(0.033)				

Note: base outcome is cash. MP is mobile payment. Base category for employment is unemployed. Robust standard errors in parentheses. Significance levels are denoted as *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Overall, there is compelling evidence that the model is appropriately specified and consistent with theory.

According to Table 13, the coefficients of mobile payment all show the expected sign, meaning that mobile payment positively affects the use of payment cards and negatively affects the use of checks for overall POS payments compared to cash. It exerts a statistically significant effect on the usage of prepaid cards relative to cash, whereas the effect is insignificant for the remaining payment instruments (i.e., check, debit card, and credit card), holding all else constant. The corresponding joint significant test (Wald test) affirms that mobile payment has no significant impact on the use of payment instruments and thus does not statistically significantly improve model fit.[23] Similar findings are provided for retail and services payments (see Tables 14, 15). This finding may reflect the fact that consumers generally do not change their payment habits at the POS simply because mobile payment technologies are available, possibly due to both force of habit and general resistance to new technology. Indeed, Humphrey et al. (1996) argue that individual payment patterns strongly depend on past compositions and are highly persistent.[24]

Estimates of the perceived characteristics of payment methods all have expected signs and are highly statistically significant. The higher the assessment of a payment method, the more likely that method is to be used, while the probability of using any of the other methods declines. In other words, individuals who view a specific payment method as relatively cheaper, more secure, more accepted, more convenient, more easily set up, and more supportive of tracking payments are more likely to use that method. Furthermore, overall evidence that education, income, being male, being retired or working—compared to being unemployed—are statistically significant factors that predict the employment of payment methods is found. For instance, more

[23] Test statistics are not provided.

[24] Another reason could be that the possibility of using mobile payment at the POS is not common. In addition, mobile payment, being new, may not be able to compensate for the benefits of traditional payment instruments.

Table 14 Nested logit estimates usage stage: retail payments

Variables		Check	Debit	Credit	Prepaid
MP		−0.509	0.115	0.109	−0.004
		(0.911)	(0.182)	(0.186)	(0.431)
Age		0.281*	−0.028	−0.048*	0.037
		(0.157)	(0.028)	(0.028)	(0.055)
Age^2		−0.002*	0.000	0.000	−0.000
		(0.001)	(0.000)	(0.000)	(0.001)
Education		−0.078	0.191***	0.286***	0.210
		(0.198)	(0.065)	(0.066)	(0.129)
Income		0.037	0.108**	0.163***	−0.350**
		(0.144)	(0.046)	(0.046)	(0.176)
Working		0.490	0.744***	0.656***	0.062
		(0.595)	(0.197)	(0.201)	(0.332)
Retired		1.304*	0.632**	0.646**	0.195
		(0.730)	(0.250)	(0.253)	(0.464)
Other employment		0.589	0.169	0.217	−0.166
		(0.542)	(0.200)	(0.204)	(0.337)
Male		−0.736*	−0.642***	−0.542***	−0.223
		(0.433)	(0.129)	(0.130)	(0.250)
Household size		−0.046	−0.012	−0.041	0.150**
		(0.166)	(0.046)	(0.048)	(0.075)
MP Internet security		−0.180	0.208**	0.182**	0.010
		(0.279)	(0.084)	(0.085)	(0.189)
MP text security		−0.348	−0.017	−0.041	0.026
		(0.290)	(0.087)	(0.088)	(0.164)
MP voice security		0.230	−0.100	−0.054	0.067
		(0.242)	(0.079)	(0.080)	(0.150)
Security	0.134***				
	(0.049)				
Setup	0.580***				
	(0.112)				
Acceptance	0.460***				
	(0.131)				
Cost	0.373***				
	(0.066)				
Records	0.449***				
	(0.081)				
Convenience	1.212***				
	(0.155)				

Table 14 continued

Variables	Check	Debit	Credit	Prepaid
Constant	−10.599**	−0.508	−0.620	−2.465*
	(5.224)	(0.766)	(0.783)	(1.445)
Observations		8430		
N		1686		
log(likelihood)		−1603		
Paper λ		1.488***		
		(0.421)		
Card λ		0.266***		
		(0.035)		

Note: base outcome is cash. MP is mobile payment. Base category for employment is unemployed. Robust standard errors in parentheses. Significance levels are denoted as *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

educated, higher income and working individuals are more likely to pay by debit and credit card for all types of POS payments compared to using cash. In addition, the likelihood of paying by payment cards rises if consumers rate the Internet security of mobile payments relatively higher.

In light of the mostly insignificant effects of mobile payment in the regression analysis, nevertheless, average marginal effects are focused on in the next section.

6.2.2 Average marginal effects

Analogous to Sect. 6.1, the average marginal effect of mobile payment for a typical person in different payment contexts according to Eq. (16) is computed. The AME_{MP} basically represents the difference in the predicted probabilities of paying by instrument j for transaction type h with and without mobile payment, holding all else constant. However, according to the model, the effects are not statistically relevant with the exception of the impact on the choice of prepaid cards for overall POS payments.

The first column of Table 16 sets out the predicted probabilities for overall POS payments. These are quite close to the actual frequencies in the sample, with the exception of cash payments (compare Tables 8, 4).[25] Thus, the overall fit of the model is good, as the choice probabilities of check, debit, credit, and prepaid card are rather precise.

The AME_{MP} of POS payments is shown in the third column of Table 16. All effects have expected signs except credit cards and their magnitude is very moderate ranging from −0.36 to +0.65 percentage points. This implies that the decision to pay by instrument j at the POS is not much influenced by mobile payment. While mobile payment typically decreases the probability to choose cash or check as a payment method at the POS (around −0.27 and −0.24 percentage points, respectively), it

[25] The predicted probabilities of cash primarily differ from the sample frequencies due to sample weights, which tend to account for underrepresented cash payments.

Table 15 Nested logit estimates usage stage: services payments

Variables		Check	Debit	Credit	Prepaid
MP		−0.685	0.048	0.046	0.358
		(0.838)	(0.207)	(0.210)	(0.282)
Age		0.099	0.005	−0.005	0.015
		(0.116)	(0.031)	(0.031)	(0.061)
Age^2		−0.001	−0.000	−0.000	−0.000
		(0.001)	(0.000)	(0.000)	(0.001)
Education		0.366	0.114	0.230***	0.116
		(0.315)	(0.087)	(0.089)	(0.130)
Income		0.036	0.106**	0.188***	0.105
		(0.165)	(0.053)	(0.053)	(0.093)
Working		0.623	0.591***	0.385*	−0.163
		(0.724)	(0.227)	(0.229)	(0.337)
Retired		1.558*	0.749**	0.809***	0.631
		(0.947)	(0.305)	(0.308)	(0.601)
Other employment		0.006	0.153	0.156	−0.306
		(0.645)	(0.223)	(0.226)	(0.364)
Male		−1.148*	−0.527***	−0.484***	−0.589**
		(0.606)	(0.168)	(0.170)	(0.262)
Household size		−0.075	−0.009	−0.051	0.069
		(0.185)	(0.053)	(0.055)	(0.071)
MP Internet security		0.741*	0.357***	0.344***	0.435***
		(0.397)	(0.114)	(0.115)	(0.164)
MP text security		−0.571	−0.072	−0.063	−0.294*
		(0.400)	(0.111)	(0.112)	(0.163)
MP voice security		−0.112	−0.117	−0.104	−0.154
		(0.261)	(0.087)	(0.089)	(0.148)
Security	0.115**				
	(0.048)				
Setup	0.496***				
	(0.113)				
Acceptance	0.533***				
	(0.133)				
Cost	0.323***				
	(0.066)				
Records	0.492***				
	(0.085)				
Convenience	0.910***				
	(0.143)				
Constant		−7.725	−1.095	−1.401	−0.830
		(5.165)	(0.875)	(0.892)	(1.390)

Table 15 continued

Variables	Check	Debit	Credit	Prepaid
Observations		8015		
N		1603		
log(likelihood)		−1666		
Paper λ		1.993**		
		(0.922)		
Card λ		0.252***		
		(0.037)		

Note: base outcome is cash. MP is mobile payment. Base category for employment is unemployed. Robust standard errors in parentheses. Significance levels are denoted as *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 16 Usage stage: AME of mobile payment for POS payments

Instrument	Predicted prob.	Predicted prob. w/o MP	Average marginal effect
Cash	39.155	39.428	−0.270
Check	3.874	4.109	−0.240
Debit	36.605	35.975	0.648
Credit	19.320	19.673	−0.364
Prepaid	1.046	0.815	0.227

Note: survey weights used. Numbers are in percentages and percentage points, respectively

Table 17 Usage stage: AME of mobile payment for retail payments

Instrument	Predicted prob.	Predicted prob. w/o MP	Average marginal effect
Cash	34.229	34.550	−0.317
Check	3.728	3.816	−0.092
Debit	39.925	39.557	0.374
Credit	20.903	20.823	0.069
Prepaid	1.215	1.254	−0.034

Note: survey weights used. Numbers are in percentages and percentage points, respectively

increases the likelihood of paying by debit or prepaid card (+0.65 and +0.23 percentage points, respectively). Ironically, the effect of mobile payment on the probability of paying by credit card is negative (−0.36 percentage points). This could be because mobile payment users prefer debit and prepaid cards that determine the underlying payment process. It is also very likely that mobile payment negatively affects the use of paper-based methods in favor of card-based methods, particularly debit card usage. This effect is more pronounced in the context of retail payments, as the magnitude of the effect on cash and checks nearly offsets the one on debit card use. Thus, mobile payment may act as a substitute for paper-based instruments, especially cash.

Similar findings are separately reported both for retail and services payments in Tables 17 and 18, respectively. Overall, the effects are not very sizeable compared

Table 18 Usage stage: AME of mobile payment for services payments

Instrument	Predicted prob.	Predicted prob. w/o MP	Average marginal effect
Cash	34.349	34.572	−0.243
Check	6.058	6.288	−0.236
Debit	36.950	36.879	0.095
Credit	20.727	20.659	0.066
Prepaid	1.915	1.602	0.317

Note: survey weights used. Numbers are in percentages and percentage points, respectively

to the choice probabilities. For retail payments, mobile payment positively affects debit and credit card usage by around 0.37 and 0.07 percentage points, respectively, whereas it negatively influences cash, check, and prepaid card use (by roughly −0.32, −0.09, and −0.03 percentage points, respectively). Moreover, mobile payment has a negative impact on the probability of using cash and check for services payments by approximately −0.24 percentage points. In contrast, it fosters the use of payment cards for services payments ranging from +0.07 to +0.32 percentage points. This could indicate that mobile payment especially facilitates electronic payment processing at places (e.g., fast food counters) where consumers typically desire a faster checkout.[26]

To conclude, there is suggestive evidence at the usage stage that mobile payment generally tends to substitute for paper-based payment methods and complement card-based instruments, especially debit cards, with regard to POS payments. However, the magnitude of the impact is not very sizeable. With respect to specific retail and services payments, these effects principally remain stable, but vary in terms of magnitude and sign. That the estimates of mobile payment are not always statistically significant, however, suggests that current individual payment compositions are not influenced by mobile payment technologies and are thus determined by other factors. The usage of payment instruments seems to be strongly habitual and unconscious, which in turn may impede the take up of innovative payment products. In addition, supply-side restrictions, that is, the non-acceptance of mobile payment by merchants, may prove a barrier to the widespread use of mobile payment technologies.

7 Plausibility check

At this stage, the question arises as to how reasonable and robust the results are. Alternative estimation strategies are not focused here since the presented test statistics of the estimated models all demonstrate that the models are well specified. Rather, the data set used with respect to the question about mobile payment usage is critically scrutinized. To this end, the latest report by Brown et al. (2015)—published by the Board of Governors of the Federal Reserve System (FRS)—who exclusively examine the adoption and use of mobile banking and mobile payment as well as individual

[26] For instance, services payments comprise purchases at bars, and fast food restaurants as well as for transportation and tolls, among others.

interaction with financial institutions facilitated by mobile phones and other technologies is drawn on.[27] The survey has been conducted online every year in December since 2011, using a representative sample of the U.S. population aged 18 and older. The latest survey is from 2014.

Comparing responses to the survey question about mobile payment usage in 2012 between the SCPC and FRS illustrates that the number of users does not vary much (18 vs. 15 %). In 2014, the latter figure provided by the FRS increased to 22 %. The FRS also shows that the median reported frequency of mobile payment was two times in the month prior to the 2014 survey, although roughly 18 % of respondents reported using this method more than five times. Further, around 27 % of mobile payment users had employed the method in the past year, but not in the month prior to the survey. This rather sporadic and low rate of usage may explain why mobile payment does not causally impact the use of conventional payment instruments in the empirical analysis above. It appears that this technology is still in its infancy (cf. Rogers 2003).

The chief reasons given by individuals for never using mobile payment are that it is easier to pay with other methods (75 %), they do not see a clear benefit from mobile payment (59 %), and they have security concerns about it (59 %) (cf. Brown et al. 2015). Thus, to make a success of mobile payment, the payment industry will need to address these issues and improve the perception of mobile payment. Interestingly, the facts and figures expressed above are similar to ones found in a recent survey in Germany conducted by the Deutsche Bundesbank (2015): a tiny share of roughly 2–4 % regularly uses mobile payment. Thus, it appears that security concerns as well as the lack of a perceived need for the service are the main rationales for non-usage.

Another striking finding relates to the funding principle of mobile payment. According to Brown et al. (2015), debit cards (55 %), credit cards (51 %), and bank account deductions (41 %) are the most ways of funding mobile purchases. It is, therefore, likely that mobile payment will affect card payments more extensively the more intensively it will be used.

8 Conclusion

This paper is the first to investigate the impact of mobile payment on the adoption and usage of traditional retail payment instruments at the POS using a comprehensive U.S. data set on individual payment patterns. Applying the random utility framework for estimation yields the following important results. First, mobile payment increases the probability of possessing all available payment instruments at the POS by roughly 2 % points and reduces the likelihood of adopting payment portfolios that include checks and only cash. This finding implies that mobile payment does not replace physical payment cards, but does act as a substitute for paper-based payment methods. Second, no causal relationship between mobile payment and the use of traditional payment means, except prepaid cards, was found. In other words, mobile payment does not statistically significantly impact the usage of payment instruments at the POS, but

[27] Unfortunately, the survey does not provide any information on the adoption and use of other payment instruments.

positively does so for prepaid cards. The estimation provides supportive evidence that mobile payment principally serves as a complement to card payments and as a substitute for paper-based payment methods such as cash and check, as it could allow for more efficient checkout. Overall, the results of the usage stage may reflect the fact that payment instrument use seems to strongly depend on other factors, including perceived characteristics of payment methods, individual habits, and automatism. This study fits into the existing literature on consumer payment choice and contributes to understanding the role of mobile payment in the retail payment landscape.

The findings have several important implications. First, the results show that the payment industry should actively promote mobile payment products, as doing so could speed the shift from paper-based products to electronic payment cards, which, in turn, is a prerequisite for faster proliferation of electronic payment transactions. The results also highlight the important difference between the extensive and intensive margin of payment products and thus should motivate private industry to expend more effort on incentivizing mobile payment usage, as more frequent use also tends to foster electronic (card) payments and, consequently, increase profits. Second, the findings imply that the overall payment system can benefit from the decreasing social costs inherent in the shift from paper- to card-based payment methods. Third, although mobile payment does not always have causal effects on the use of payment means, policymakers should be aware of different consumer regulations and regulatory agencies that cover the payment method used to fund mobile payment (cf. Martin 2012).

The study is subject to a number of limitations. The information on mobile payment usage in the survey may not be sufficient to analyze its impact in detail. For instance, it is unclear how many times mobile payment is deployed at the POS prior to the survey, which could affect the use of traditional payment instruments more significantly. In addition, the data set may suffer from recall effects since respondents may have forgotten or could be conceptually uncertain about the number of card payments made via a mobile device. If such is the case, it would lead to a possible underestimation of the corresponding effects. In addition, although the multiple forms of mobile payment enable paying at the POS, the survey does not provide sufficient information on whether mobile payments have been solely used for POS payments. In this sense, the channels through which mobile payment affects traditional payment instrument use may be confounded. Therefore, payment surveys that collect detailed information on the usage of different mobile payment types would obtain more accurate results.

Furthermore, missing information about supply-side factors in the data set could lead to correlated error terms. Because mobile payment represents a relatively new form of payment, it could be less accepted by merchants, for instance, due to inadequate infrastructure or personal reservations. As a consequence, the unavailability of mobile payment at the POS could result in negative feedback effects for consumers and thus in less mobile payment usage. Some evidence in support of this idea is provided by Rysman (2007), who finds that people tend to choose a specific card brand when a large number of merchants accept this brand. Thus, data on merchants' mobile payment acceptance would help mitigate this issue.

With respect to external validity, the extent to which the findings can be generalized to other countries is uncertain, as major cultural and institutional differences in payment markets across countries are prevalent. For instance, the heavy and earlier reliance on payment cards rather than credit transfer and cash in the United States compared to Europe could have induced U.S. consumers to be more open-minded toward innovative payment products in terms of adoption and usage. Therefore, the magnitude and significance of the estimated effects of mobile payment may differ across payment areas. In addition, there are many different types of mobile payment technology with varying incidence across countries. For example, mobile payment may be quite popular in developing countries for person-to-person payments due to these countries' vast number of unbanked and underbanked persons, whereas it may be more frequently used at the POS in developed countries. Thus, the impact of mobile payment across countries may vary in terms of the underlying technological concept.

In the end, it remains unclear how mobile payment exactly affects the use of traditional payment instruments. Possibly it is improved efficiency and convenience compared to traditional payment instruments that drives its deployment, as several studies presume (see Sect. 2). However, to obtain a clear picture of the specific channels through which mobile payment has an effect on other payment methods and to provide detailed results of its multiple forms of applications and features, it is necessary to collect qualitatively improved data on mobile payment usage in all its facets; this is left for future research.

Acknowledgments The author thanks the anonymous referee for his/her constructive comments and valuable inputs, which substantially improved this paper.

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